TRANSLATION OF EUROPEAN PATENT

0 149 197 B1

⑲ Europäisches Patentamt

European Patent Office

Office européen des brevets

⑪ Publication number: **0 149 197**
B1

⑫ **EUROPEAN PATENT SPECIFICATION**

㊹ Pharmaceutical compositions containing drugs which are instable or sparingly soluble in water and methods for their preparation

�73 Proprietor: JANSSEN PHARMACEUTICA N.V.
Turnhoutsebaan 30
B-2340 Beerse (BE)

�72 Inventor: Brauns, Ulrich
Föhrer Weg 7
D-2300 Kiel (DE)
Erfinder: Müller, B. W. W., Prof., Dr.
Schlotfeldtsberg 14a
D-2302 Flintbek (DE)

㉔ Representative: UEXKÜLL & STOLBERG Patentanwälte
Beselerstrasse 4
D-2000 Hamburg 52 (DE)

EP 0 149 197 B1

Pharmaceutical compositions containing drugs which are instable or sparingly soluble in water and methods for their preparation

Description

5   The invention relates to pharmaceutical compositions containing drugs which are instable or only sparingly soluble in water, and methods for their preparation. The compositions are characterized by increased water solubility and improved stability.

10   A large number of drugs is only poorly or sparingly soluble in water so that suitable application forms like drop solutions or injection solutions are being prepared using other polar additives like propylene glycol etc. If the drug molecule has basic or acidic groups there exists the further possibility of increasing the water solubility by salt formation. As a rule this results in decreased efficacy or impaired chemical stability. Due to the shifted

15   distribution equilibrium the drug may penetrate the lipophilic membrane only slowly corresponding to the concentration of the non-dissociated fraction while the ionic fraction may be subject to a rapid hydrolytic decomposition.

Additional "water-like" solvents like low molecular polyethylene glycols or 1,2-propylene glycol are therefore used in the preparation of aqueous

20   solutions of sparingly water-soluble drugs which glycols, however, cannot be considered pharmacologically inert, or the drug is solubilized using surfactants so that the drug molecules are occluded in micelles. This solubilization has numerous disadvantages: The surfactant molecules used have frequently a strongly haemolytic effect and the drug needs to pass out

25   of the micelle by diffusion after the application. This results in a retard effect (compare B.W. Müller, Gelbe Reihe, Vol. X, pages 132ff (1983)).

Accordingly it may be stated that there exists no satisfactory and generally applicable method of solubilization.

For solid drugs it is also important to render the sparingly water-soluble drug water-soluble since a good solubility increases the bioavailability of the drug. It has been described that inclusion compounds, e.g. with urea or complexes of polyvinyl pyrrolidone may improve the solubility of a compound but in aqueous solution they are not stable. Such inclusion compounds are therefore at best suitable for solid application forms of drugs.

This is different when using α-, β-, and γ-cyclodextrin which can bind a drug in its ring also in aqueous solution (W. Sänger, Angewandte Chemie 92, 343 (1980)). However, it is disadvantageous that the β-cyclodextrin itself is only poorly water-soluble (1.8 g/100 mL) so that the therapeutically necessary drug concentrations are not achieved.

If a derivative is formed of the cyclodextrin its solubility and therefore the amount of dissolved drug may be considerably increased. Thus, German Offenlegungsschrift 31 18 218 discloses a solubilization method using methylated β-cyclodextrin as monomethyl derivative with 7 methyl groups and especially as dimethyl derivative with 14 methyl groups. With the 2,6-di-0-methyl derivative it is for instance possible to increase the water solubility of indomethacin 20.4-fold and that of digitoxin 81.6-fold.

In WO-A-820 051 inclusion complexes of retinoids with cyclodextrins and cyclodextrin derivatives are described. The rationale of the publication (or: the publication is based on the problem...) is the reduction of toxic side effects of retinoids by modification of the molecular structure and/or by complexation with cyclodextrins. The solubility of these substances (retinoids) in lipids shall be lowered and the tendency of accumulation in adipose tissue shall be reduced or avoided. In the publication, α, β and γ cyclodextrins and their derivatives are described to be equally suitable for complexation whereas mainly methoxy-derivatives of α, β and γ cyclodextrins are mentioned (listed) as examples.

However, for therapeutical use the methyl derivatives of β-cyclodextrin show serious draw backs. Due to their increased lipophilicity they have a haemolytic effect and they further cause irritations of the mucosa and eyes. Their acute intravenous toxicity is still higher than the already considerable toxicity of the unsubstituted β-cyclodextrin. It is a further serious disadvantage for the practical application that the solubility of the dimethyl β-cyclodextrin and its complexes suffers a steep decrease at higher temperatures so that crystalline dextrin precipitates upon heating. This phenomenon makes it very difficult to sterilize the solutions at the usual temperatures of 100 to 121°C.

Quite surprisingly it has now been found that certain other β-cyclodextrin derivatives can form inclusion compounds which also considerably increase the water-solubility of sparingly water-soluble and instable drugs without showing the disadvantages described above.

Subject of the invention are therefore novel pharmaceutical compositions comprising inclusion compounds of only sparingly water-soluble or in water instable drugs with a partially etherified β-cyclodextrin in which the residues are hydroxyethyl, hydroxypropyl or dihydroxypropyl groups and part of the residues may optionally be methyl or ethyl groups. The β-cyclodextrin ether have a water-solubility of more than 1.8 g in 100 mL water, except for inclusion complexes of retinoids with β-cyclodextrin ethers if the residues are hydroxyethyl, hydroxypropyl or dihydroxypropyl groups. The use of partially methylated β-cyclodextrin ethers with 7 to 14 methyl groups in the β-cyclodextrin molecule, as they are known from German Offenlegungsschrift 31 18 218 do not come under the present invention. Furthermore, inclusion complexes of retinoids with β-cyclodextrin ethers are excluded, as far as methyl-ethyl- and 2-hydroxyethyl substituents are concerned (WO-A-820 051).

β-cyclodextrin is a compound with ring structure consisting of 7 anhydro glucose units; it is also referred to as cycloheptaamylose. Each of the 7 glucose rings contains in 2-, 3-, and 6-position three hydroxy groups which may be etherified. In the partially etherified β-cyclodextrin derivatives used according to the invention only part of these hydroxy groups is etherified with hydroxyalkyl groups and optionally further with methyl or ethyl groups. When etherifying with 5-hydroxy alkyl groups which can be carried out by reaction with the corresponding alkylene oxides, the degree of substitution is stated as molar substitution (MS), viz. in mole alkylene oxide per anhydroglucose unit, compare US patent specification 34 59 731, column 4. In the hydroxyalkyl ethers of β-cyclodextrin used in accordance with the invention the molar substitution is between 0.05 and 10, preferably between 0.2 and 2. Particularly preferred is a molar substitution of about 0.25 to about 1.

The etherification with alkyl groups may be stated directly as degree of substitution (DS) per glucose unit which - as stated above - is 3 for complete substitution. Partially etherified β-cyclodextrins are used within the invention which comprise besides hydroxyalkyl groups also alkyl groups, especially methyl or ethyl groups, up to a degree of substitution of 0.05 to 2.0, preferably 0.2 to 1.5. Most preferably the degree of substitution with alkyl groups is between about 0.5 and about 1.2.

The molar ratio of drug to β-cyclodextrin ether is preferably about 1:6 to 4:1, especially about 1:2 to 1:1. As a rule it is preferred to use the complex forming agent in a molar excess.

Useful complex forming agents are especially the hydroxyethyl, hydroxypropyl and dihydroxypropyl ether, their corresponding mixed ethers, and further mixed ethers with methyl or ethyl groups, such as methyl-hydroxyethyl, methyl-hydroxypropyl, ethyl-hydroxyethyl and ethyl-hydroxypropyl ether of β-cyclodextrin.

The preparation of the hydroxyalkyl ethers of β-cyclodextrin may be carried out using the method of US patent specification 34 59 731. Suitable preparation methods for β-cyclodextrin ethers may further be found in J. Szejtli et al., Stärke 32, 165 (1980) and A.P. Croft and R.A. Bartsch, Tetrahedron 39, 1417 (1983). Mixed ethers of β-cyclodextrin can be prepared by reacting β-cyclodextrin in a basic liquid reeaction medium comprising an akali metal hydroxide, water and optionally at least one organic solvent (e.g. dimethoxyethane or isopropanol) with at least two different hydroxyalkylating and optionally alkylating etherifying agents (e.g. ethylene oxide, propylene oxide, methyl or ethyl chloride).

Drugs exhibiting a significantly increased water-solubility and improved stability, respectively, after having been transferred into inclusion compounds with the above-mentioned β-cyclodextrin ethers are those having the required shape and size, i.e. which fit into the cavity of the β-cyclodextrin ring system. This includes for instance non-steroid anti-rheumatic agents, steroids, cardiac glycosides and derivatives of benzodiazepine, benzimidazole, piperidine, piperazine, imidazole or triazole.

Useful benzimidazole derivatives are thiabendazole, fuberidazole, oxibendazole, parbendazole, cambendazole, mebendazole, fenbendazole, flubendazole, albendazole, oxfendazole, nocodazole and astemisole. Suitable piperadine derivatives are fluspirilene, pimozide, penfluridole, loperamide, astemizole, ketanserine, levocabastine, cisapride, altanserine, and ritanserine. Suitable piperazine derivatives include lidoflazine, flunarizine, mianserine, oxatomide, mioflazine and cinnarizine. Examples of suitable imidazole derivatives are metronidazole, ornidazole, ipronidazole, tinidazole, isoconazole, nimorazole, burimamide, metiamide, metomidate, enilconazole, etomidate, econazole, clotrimazole, carnidazole, cimetidine, docodazole, sulconazole, parconazole, orconazole, butoconazole, triadiminole, tioconazole, valconazole, fluotrimazole, ketoconazole, oxiconazole, lombazole, bifonazole,

oxmetidine, fenticonazole and tubulazole. As suitable triazole derivatives there may be mentioned virazole, itraconazole and terconazole.

Particularly valuable pharmaceutical compositions are obtained when converting etomidate, ketoconazole, tubulazole, itraconazole, levocabastine or flunarizine into a water-soluble form using the complex forming agents of the invention. Such compositions are therefore a special subject of the present invention.

The invention is further directed to a method of preparing pharmaceutical compositions of sparingly water-soluble or water-instable drugs which is characterized by dissolving the β-cyclodextrin ether in water and adding thereto the selected drug as well as optionally drying the solution of the formed inclusion compound using methods known per se. Formation of the solution may take place at temperatures between 15 and 35°C.

The drug is suitably added stepwise. The water may further comprise physiologically compatible compounds such as sodium chloride, potassium nitrate, glucose, mannitole, sorbitol, xylitol or buffers such as phosphate, acetate or citrate buffer.

Using β-cyclodextrin ethers in accordance with the invention it is possible to prepare application forms of drugs for oral, parenteral or topical application, e.g. infusion and injection solutions, drop solutions (e.g. eye drops or nasal drops), sprays, aerosols, syrups, and medical baths.

The aqueous solutions may further comprise suitable physiologically compatible preserving agents such as quaternary ammonium soaps or chlorbutanol.

For the preparation of solid formulations the solutions of the inclusion compounds are dried using conventional methods; thus the water may be

evaporated in a rotation evaporator or by lyophilization. The residue is pulverized and, optionally after addition of further inert ingredients, converted into uncoated or coated tablets, suppositories, capsules, creams or ointments.

The following examples serve to illustrate the invention which, however, is not restricted to the examples.

The phosphate buffer solution mentioned in the examples had a pH of 6.6 and the following composition:

KH_2PO_4	68.05 g
NaOH	7.12 g
Aqua demin. ad.	5000.0 g

All percentages are percent by weight.

Example 1

Starting from a 7% stock solution of hydroxyethyl β-cyclodextrin (MS 0.43) in phosphate buffer solution a dilution series was prepared so that the complex forming agent concentration was increased in steps of 1%. 3 mL of these solutions were pipetted into 5 mL snap-top-glasses containing the drug to be tested. After shaking for 24 hours at 25°C the solution was filtered through a membrane filter (0.22 microns) and the dissolved drug content was determined spectrophotometrically. Figures 1, 3 and 4 show the increase of the drug concentration in solution in relation to the concentration of the complex forming agent for indomethacin (figure 1), piroxicam (figure 3) and diazepam (figure 4). The maximum drug concentration is limited by the saturation solubility of the cyclodextrin derivative in the buffer which in the case of hydroxyethyl-β-cyclodextrin (MS 0.43) is reached at 7.2 g/100 mL.

When comparing for instance the results obtained with indomethacin to those given in German Offenlegungsschrift 31 18 218 for 2,6-di-0-methyl-β-cyclodextrin (figure 2) it will be observed that the hydroxyethyl derivative has a significantly higher complex formation constant (compare the different slopes in figures 1 and 2).

Example 2

A.   The saturation solubility at 25°C of different drugs was determined using a 10% hydroxypropyl-β-cyclodextrin solution (MS 0.35) in phosphate buffer solution under the same conditions as in example 1. The saturation solubilities S_1 in phosphate buffer solution and S_2 in phosphate buffer solution and 10% added hydroxypropyl-β-cyclodextrin are given in table 1.

Table 1

Drugs	S_1 (mg/mL)	S_2 (mg/mL)	Ratio S_1:S_2
Indomethacin	0.19	5.72	1: 30.1
Digitoxin	0.002	1.685	1: 842.5
Progesterone	0.0071	7.69	1:1083.0
Dexamethasone	0.083	14.28	1: 172.0
Hydrocortisone	0.36	21.58	1: 59.9
Diazepam	0.032	0.94	1: 29.4

B.   The solubility of drugs in a 4% aqueous solution of hydroxypropyl-methyl-β-cyclodextrin (DS 0.96; MS 0.43) was determined in a similar manner. The results obtained are summarized in the following table 2 in which the ratio R of the saturation solubility in water or at the stated pH, respectively, with and without addition of β-cyclodextrin derivative is stated for each drug. The solutions

prepared according the invention were further found to be significantly more stable when compared with aqueous solutions.

Table 2

Drug		R
Itraconazole	at pH 5	96
	at pH 2.5	75
Flunarizine		18
Levocabastine	at pH 9.5	81
	at pH 7.4	8
Ketoconazole		85
Flubendazole		30
Tubulazole		43
Cisapride		3
Loperamide		62
Etomidate		8.5
Cinnarizine	at pH 5	28
	at pH 3	12

Example 3

In 10 mL phosphate buffer solution 0.7 g hydroxyethyl-β-cyclodextrin (MS 0.43) were dissolved together with 0.04 g indomethacin at 25°C until a clear solution was formed. This solution was filtered through a membrane filter (0.22 microns) and filled under laminar flow into a pre-sterilized injection bottle which was stored at 21°C (B). In a parallel test a saturated indomethacin solution in a phosphate buffer solution (0.21 mg/mL) was stored under the same conditions (A). The drug concentrations determined by high pressure liquid chromatography are given in table 3. The great improved stability of the composition according to the invention is apparent.

Table 3

Storing Time in weeks	Indomethacin A	Content (%) B
0	100.1	99.7
2	91.2	99.9
4	79.1	98.1
6	69.8	98.6
8	64.8	98.4

Example 4 (Injectable formulation)

0.35 g hydroxypropyl-β-cyclodextrin (MS 0.35) were dissolved in 5 mL of physiological sodium chloride solution and warmed to about 35°C whereafter 3 mg diazepam were added. After storing for a short time a clear solution was obtained which was filled into an ampule after filtration through a membrane filter (0.45 microns).

Example 5 (Tablet)

In 100 mL water 7 g hydroxyethyl-β-cyclodextrin (MS 0.43) and 0.5 g medroxyprogesterone acetate were dissolved. The water was then evaporated in a rotation evaporator. The residue (75 mg) was powdered and after addition of 366 mg calcium hydrogen phosphate.$2H_2O$, 60 mg corn starch, 120 mg cellulose powder (microcrystalline), 4.2 mg highly dispersed silica (AEROSIL[R] 200) and 4.8 mg magnesium stearate tablets with a weight of 630.0 mg and comprising 5 mg drug per unit dose were made. The dissolution rate of the medroxyprogesterone acetate from this formulation is 21 times higher when compared to a tablet comprising the same inert ingredients without addition of the β-cyclodextrin ether.

Example 6

5 g hydroxyethyl-β-cyclodextrin (MS 0.43) and 14 mg vitamin A-acetate were dissolved under stirring in 100 mL water or sugar solution (5% aqueous solution) within 2.5 hours under a nitrogen atmosphere. After filtration through a membrane filter (0.45 microns) the solution was filled into ampules and sterilized or filled into dropper bottles with addition of 0.4% chlor butanol as preserving agent.

Example 7

5 or 7.5 g hydroxyethyl-β-cyclodextrin (MS 0.43) and 0.5 or 0.75 g Lidocaine were dissolved in 100 mL of physiological sodium chloride solution at 30°C (B). Injection solutions, eye droplets and solutions for topical use were prepared therefrom as described in example 6. When comparing the anaethesic effect of these solutions in animal tests with an aqueous lidocaine HCl solution (A) one observes an extension of the duration of the effect by 300%. Test: rats, injection of 0.1 mL into the tail root in the vicinity of the right or left nerve filaments and electrical irritation. The test results are summarized in table 4.

Table 4

Drug Concentration (%)	Duration of effect (min)		Extension %
	A	B	
0.5	56	163	291
0.75	118	390	330

Example 8

6 mg dexamethasone and 100 mg hydroxyethyl-β-cyclodextrin (MS 0.43) were dissolved in 5 mL water, sterilized by filtration through a membrane

filter (0.22 microns) and packed into an aerosol container allowing to dispense 0.1 mL per dose.

Example 9

The acute intravenous toxicity of some β-cyclodextrins was tested on rats with the following results. It was surprisingly found that the toxicity of the derivatives used according to the invention is lower by an entire order of magnitude.

Table 5

	LD$_{50}$ in rats (i.v.) in mg/Kg bodyweight
β-cyclodextrin	453
dimethyl-β-cyclodextrin (DS 2.0)	200-207
hydroxypropyl-methyl- β-cyclodextrin (DS 0.96; MS 0.43)	> 2000*

* a higher dose has not been tested. In mice the value was > 4000 mg/Kg.

The haemolytic effect of the methylether according to German Offenlegungsschrift 31 18 218 was compared to that of an ether used according to the invention. To this end 100 μl of a physiological sodium chloride solution with a cyclodextrin content of 10%, 800 μl of a buffer (400 mg MOPS, 36 mg Na$_2$HPO$_4$. 2 H$_2$O, 1.6 g NaCl in 200 mL H$_2$O) and 100 μl of a suspension of human red blood cells (three times washed with sodium chloride solution) were mixed for 30 minutes at 37°C. Thereafter the mixture was centrifuged and the optical density was determined at 540 nm.

Controls:

a) 100 μl sodium chloride solution + buffer → 0% haemolysis

b) 900 μl water → 100% haemolysis.

The results obtained are summarized in the following table 6 in which the concentrations are stated at which 50% and 100% haemolysis occurred.

Table 6

Substance	$C_{50}\%$	$C_{100}\%$
Dimethyl-β-CD (DS 2.0)	0.33%	0.5%
Methyl-β-CD (DS 1.79)	0.53	0.8
Hydroxypropyl-methyl-β-CD (DS 0.96; MS 0.43%)	1.5	4

The results show that the haemolytic effect of the hydroxypropylmethyl ether is about 5 to 8 times weaker than that of the dimethyl ether according to the prior art. Animal tests have further shown that the hydroxyalkyl ethers do not cause irritation of the mucosa and eyes in contrast to the methyl ethers.

Claims

1. A pharmaceutical preparation containing inclusion complexes of medicinal substances which are sparingly water-soluble or are instable in water, with a partially etherified β-cyclodextrin, the ether substituents of which are hydroxyethyl, hydroxypropyl or dihydroxypropyl groups, wherein one portion of the ether substituents may optionally be methyl or ethyl groups and the β-cyclodextrin ether has a water-solubility of more than 1.8 g in 100 mL of water,

wherein inclusion complexes of retinoids with β-cyclodextrin ethers
are excluded insofar as their ether substituents are methyl, ethyl and
2-hydroxy-ethyl groups.

2.   A preparation according to Claim 1, characterized in that it contains
a partially etherified β-cyclodextrin which has a molar degree of
substitution for the hydroxyalkyl substituents of from 0.05 to 10 and
a degree of substitution for the alkyl substituents of from 0.05 to 2.0.

3.   A preparation according to either Claim 1 or Claim 2, characterized
in that it contains the medicinal substance and the β-cyclodextrin
ether in a molar ratio of from 1:6 to 4:1.

4.   A preparation according to any one of Claims 1 to 3, characterized
in that as medicinal substance it contains a non-steroid antirheumatic
agent, a steroid, a cardiac glycoside or derivatives of benzodiazepin,
benzimidazole, piperidine, piperazine, imidazole or triazole.

5.   A preparation according to any one of Claims 1 to 4, characterized
in that as medicinal substance it contains etomidate.

6.   A preparation according to any one of Claims 1 to 4, characterized
in that as medicinal substance it contains ketoconazole.

7.   A preparation according to any one of Claims 1 to 4, characterized
in that as medicinal substance it contains itraconazole.

8.   A preparation according to any one of Claims 1 to 4, characterized
in that as medicinal substance it contains levocabastine.

9.   A preparation according to any one of Claims 1 to 4, characterized
in that as medicinal substance it contains flunarizine.

10. A preparation according to any one of Claims 1 to 4, characterized in that as medicinal substance it contains tubulazole.

11. A process for the preparation of a pharmaceutical preparation according to any one of Claims 1 to 10, characterized in that the β-cyclodextrin ether is dissolved in water and the corresponding medicinal substance is added and, optionally, the resultant solution of the inclusion complex is dried in accordance with per se known methods.

12. A process according to Claim 11, characterized in that the residue obtained after removal of the solvent is pulverized and, optionally after the addition of further adjuvants, is converted into a solid administration form.

13. A process according to Claim 11 or Claim 12, characterized in that further physiologically compatible substances are added to the water.

14. A process according to Claim 13, characterized in that common salt, glucose, mannitol, sorbitol, xylitol or a phosphate or citrate buffer is added to the water.
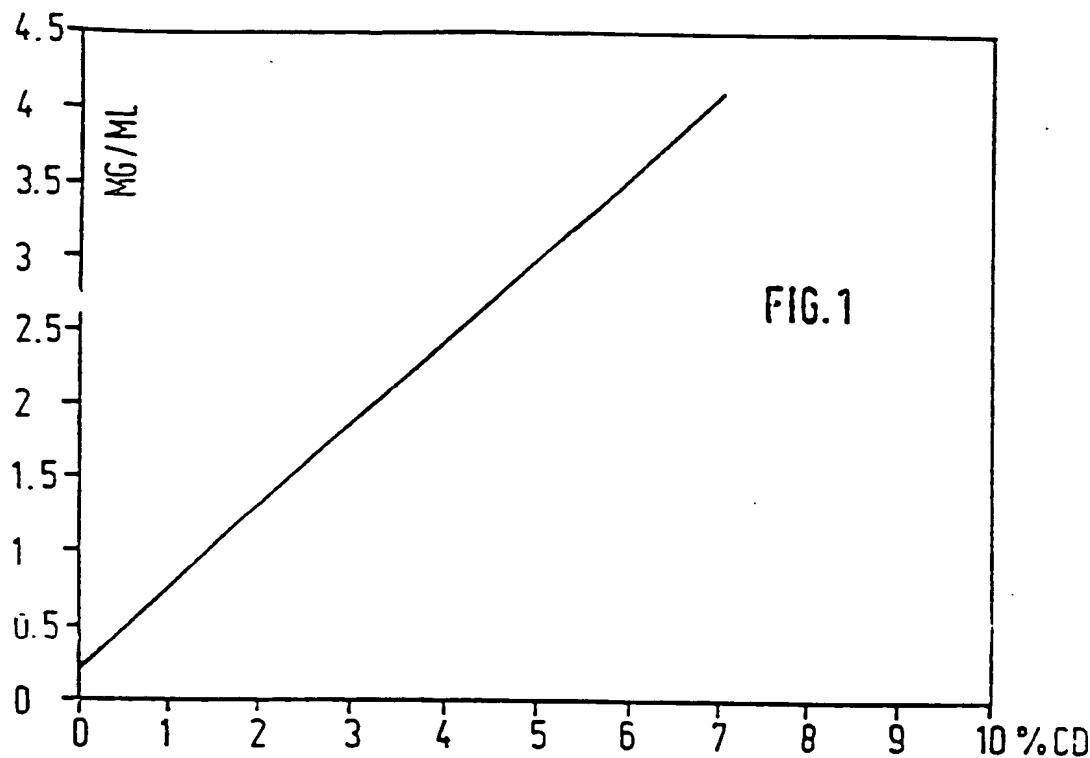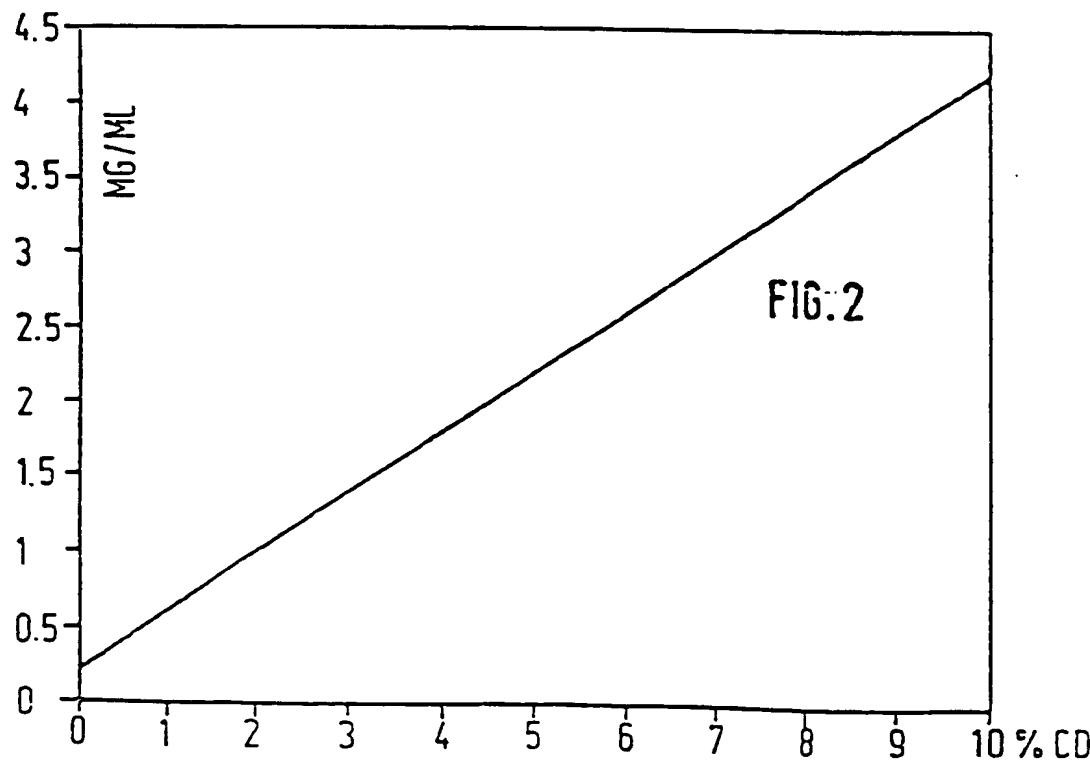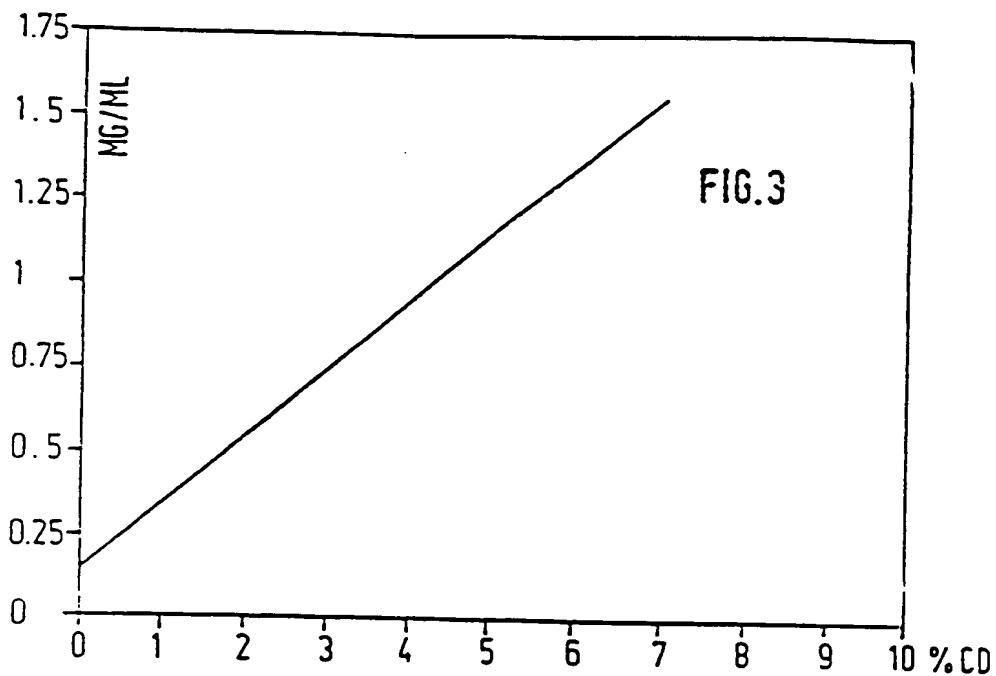
FIG.1

FIG.2

FIG.3

FIG.4